INTRAGUILD PREDATION MODEL WITH DISEASE

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A dissertation submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Science (Mathematics)

Faculty of Science
Universiti Teknologi Malaysia

NOVEMBER 2009

Dedicated to my beloved husband,
En. Abdul Hafiz Abdul Raof
my daughter,
Adillya Batrisya Abdul Hafiz
my parent,
En. A. Wahab Mat Tahir and Pn. Hamidah Mat Yatin,
my sister,
Cik Juyana A. Wahab

&

my supervisor,

Dr. Faridah Mustapha

ACKNOWLEDGEMENTS

Alhamdulillah, with His will has allowed me to complete this research.

First and foremost, I would like to thank Dr. Faridah Mustapha, my supervisor, for her support throughout this project. Her advices on both content and presentation has been superb, and quite simply, this project would not have been possible without her help. She also provided invaluable feedback on the strength and weakness of initial drafts. Thank also goes to Miss Nurul Aini Mohd Fauzi, research assistant of Faculty of Sciences (UTM) who provided expert assistance in completing this research. She also provided extremely constructive comments on the draft. I am also indebted to Universiti Teknologi Mara (UiTM) for funding my M.Sc study. My appreciation also goes to my parent for their unconditional loving support. A special note of gratitude goes to my dear husband, Abdul Hafiz Abdul Raof for his support, understanding and encouragement for all I needed during my graduate study. I would also like to thank my friends especially Nazihah Ismail, Azwani Alias and Nor Hidayu Nawi who were always with me during this semester for their kind support and for everything they taught me. It is impossible to list the many friends and colleagues who over the year have assisted the development of ideas that have resulted in this research. To each of these people I express my sincere appreciation.

ABSTRACT

Ecosystem stability is an important issue in conservation of biodiversity. The stability of predator prey systems or competitive systems has been studied extensively. Although the two fields have been the subject of widespread research recently, no work has been done to study the effect of a disease on an environment where three species; predator, prey and resource present. Here we analyze modification of Intraguild Predation (IGP) model to account for a disease spreading among prey. We chose the simplest epidemiological model, SI model. Here, we consider the simple mass action incidence. We analyze the stability equilibrium points by using Ruth-Hurwitz criteria. Numerical examples will be introduced to show the stability point. The result seems to indicate that either the disease dies out or both species eventually become infected.

ABSTRAK

Kestabilan ekosistem adalah isu penting dalam pemuliharaan kepelbagaian biologi. Sistem mangsa pemangsa dan kompetatif telah pun dikaji secara meluas. Pada masa kini, walaupun kedua-dua bidang tersebut dikaji secara terperinci, masih belum ada sebarang kajian tentang kesan penyakit dalam persekitaran kehidupan di mana wujud ketiga-tiga spesis iaitu mangsa, pemangsa dan sumber makanan semulajadi. Dalam kajian ini, kami menganalisa model pemangsaan 'intraguild' mengenai penyakit yang tersebar dikalangan pemangsa. Kami telah memilih model epidemologi ringkas iaitu model SI. Dalam kajian ini, kami mengambil kira jisim pergerakan mudah. Kami menganalisa kestabilan titik keseimbangan menggunakan aplikasi criteria Ruth-Hurwitz. Contoh berangka digunakan untuk menunjukkan titik kestabilan. Dalam penemuan kajian ini, kite dapat lihat sama ada penyakit lenyap atau pun kedua-dua sepsis dijangkiti.

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LIST OF SYMBOLS

N_i	-	number of individuals in species i
r_i	-	intrinsic per capita growth rate per species i
K_i	-	environmental carrying capacity for species i
α_{ij}	-	per capita inhibiting effect of species j on the population growth rate of species i
$\frac{1}{K_i}$	-	inhibition of species i on its own growth
$\frac{\alpha_{ij}}{K_i}$	-	inhibition of species j on the growth of species i
E_i	-	equilibrium point for solution i
N	-	biomass density of prey
N_S	-	biomass density of susceptible IG prey
N_I	-	biomass density of infected IG prey
P	-	biomass density of predator
Z	-	biomass density of basal resource
S	-	number of individuals not yet infected with the disease
I	-	number of individuals who have been infected with the disease
R	-	individuals who have been infected and then recovered from the disease
λ_i	-	eigenvalue i
a	-	predation rates on the common resource for the IG prey

a'	-	predation rates on the common resource for the IG predator
d	-	IG predation rates on n
m	-	density independent mortality rates for IG prey
m'	-	density independent mortality rates for IG prey for IG predator
b	-	predation rate into offspring for IG prey
b'	-	predation rate into offspring for IG predator by consuming basal resource
c	-	predation rate into offspring for IG predator by consuming IG prey
K	-	carrying capacity for the common resource
α	-	non-dimensionalized predation rate into offspring for IG predator by consuming basal resource
β	-	non-dimensionalized predation rate into offspring for IG predator by IG prey
δ	-	non-dimensionalized mortality rate for IG predator
ρ	-	non-dimensionalized predation rate into offspring for IG predator by consuming basal resource
χ	-	non-dimensionalized IG predation rate onto IG prey
τ	-	non-dimensionalized mortality rate for IG prey
ε	-	non-dimensionalized simple mass action among the IG prey
υ	-	non-dimensionalized conversion rate of predation upon infected IG prey
ω	-	non-dimensionalized predation rate upon infected IG prey
θ	-	non-dimensionalized recovery rate from infective to susceptible

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Venturino (1992) in his study said that the study of interacting species has already begun in the first part of the century. It has received a renewed interest in the past fifteen years in the mathematical literature. Major discoveries in biology have changed the direction of science. From the study of the sexual life of oysters, which was in some sense boring for the previous generations, biology has become today the Queen of Science. All hardcore fields, such as physics, mathematics, chemistry, and computer science are now necessary for the big adventure of unraveling the secrets of life and conversely, the mathematical sciences are all now enthusiastically inspired by biological concepts, to the extent that more and more theoreticians are interacting with biologists. Actually, it is not an understatement to say that biology has a Viagra effect on the old classical fields. What is today the role of a theoretician among the biologists, eager to incorporate new concepts? An important part of biology, besides amassing new experimental information, is the explanation and prediction of new phenomena by applying the quantitative laws of physical chemistry, that is, by quantifying phenomena in mathematical terms, not by merely fitting curve with Numerical Recipes in Matlab. Theory is not a painting of the real but it gives the framework for quantitative computations, analysis and prediction. Data analysis is only small fraction of statistics. The putting together of the pieces of the puzzle of life begins with the understanding the life of a protein, a microstructure, a cell, a network, and finally, the life of a living organism. In order to explain how a pure theoretician, can contribute to the analysis of biological systems, let us review some selected open questions.

Predation is one of the examples of interaction. Predation occurs when one animal (the predator) eats another living animal (the prey) to utilize the energy and nutrients from the body of the prey for growth, maintenance or reproduction. Predation is often distinguished from herbivory by requiring that the prey be an animal rather than a plant or other type of organism (bacteria). Population dynamics refers to changes in the sizes of populations of organisms through time, and predator-prey interactions may play an important role in explaining the population dynamics of many species. They are a type of antagonistic interaction, in which the population of one species (predators) has a negative effect on the population of a second (prey), while the second has a positive effect on the first. For population dynamics, predator-prey interactions are similar to other types of antagonistic interactions, such as pathogen-host and herbivore-plant interactions.

Many insect predators that share the same prey species are also quite likely to kill and devour each other. This is called Intraguild Predation (IGP), since it is predation within the guild of predators. IGP is a composition of three species community consisting of resource, consumer and predator. IGP is a special case of omnivory, induces two major differences with traditional linear food chain models: the potential for the occurrence of two alternative stable equilibria at intermediate levels of resource productivity and the extinction of the consumer at high productivities. At low productivities, the consumer dominates, while at intermediate productivities, the predator and the consumer can coexist. These theoretical results indicate that the conditions for stable food chains involving IGP cannot involve strong competition for the bottommost resources. Predator-prey interactions may have a large impact on the overall properties of a community. For example, most terrestrial communities are green; suggesting that predation on herbivores is great enough to stop them from consuming the majority of plant material. In contrast, the biomass of herbivorous zooplankton in many aquatic communities is greater than the biomass of the photosynthetic phytoplankton, suggesting that predation on zooplankton is not enough to keep these communities green.

1.2 Problem Statements

Interaction between individuals and species in the real world are complex processes. Every living creature grows, reproduces and eventually dies. In order to survive, an individual uses its environment for food and protection to its own advantage. Population sizes of species are affected not only by ecological interactions such as competition, predation and parasitism, but also by the effects of infectious diseases. One host species can exclude another by means of a shared infectious disease. This model suggests that apparent competitive dominance can result if individuals of one species, as compared to individuals of other species, have a higher growth rate when uninfected, are less susceptible to becoming infected, or have a higher tolerance to the disease. The higher tolerance to disease of individuals of one species may result from their faster recovery, lower death rates or higher reproductive rates. For many diseases, long time behaviour of disease transmission is related to initial positions. If the initial value of infective numbers is large, which means we have a large invasion of a disease, the disease will be persistent. If the initial value of infective numbers is small, which corresponds to a small invasion of a disease, the disease will be extinct. The study of such population ecology can help us understand the growth, extinctions and changes in distribution of populations and the underlying processes which determine these changes.

1.3 Objectives of Study

The objectives of this study are:

1. To formulate a mathematical model of Intraguild Predation (IGP) population with infectious diseases.
2. To find the equilibrium points of the IGP model with disease.
3. To analyze the stability of the equilibrium points of IGP model with disease.

1.4 Scope of Study

This study will be focused on unstructured IGP populations. For the purpose of this study, we shall only concentrate on two species population with an infectious disease for one species at one time. We only consider *SI* model and only one type of ways in which individual contract the disease which is mass action incidence.

1.5 Significant of Study

The findings from this study will contribute towards an enhanced understanding of IGP among species and the effect of diseases on the dynamics of the population. The key result in this model is that the diseases must either die out in both species or remain endemic in both species.